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Afforestation Generated Kyoto Compliant Carbon Offsets: A Case Study in Northeastern Ontario

Jeff Biggs

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Afforestation Generated Kyoto Compliant Carbon Offsets:
A Case Study in Northeastern Ontario

by

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Abstract

With the first commitment period beginning in 2008, resource managers are starting to consider the various management options available to them under the Kyoto Protocol. Though many papers discuss the potential for generating carbon offsets through afforestation at national, provincial and regional scales, none examine the factors critical to decision makers at the management unit level. This paper uses the best available modelling and economic data and applies it at the scale of the Timmins Management Unit (TMU), concentrating on the quality and availability of carbon budget models, domestic carbon market concerns (including price, leakage and permanence) and the presence of an enabling environment (considering government support, afforestation expertise, willingness among managers and land availability). A modelling exercise is then undertaken using GORCAM-WC1 under several scenarios, with ownership, leading species, investment horizon, site productivity and price as variable. The case study and model demonstrate that under current institutional frameworks and the guidelines of the Kyoto Protocol, afforestation projects with the purpose of generating carbon offsets in the TMU are not viable investments for the first commitment period, though it also shows that such projects will be profitable under certain conditions if constraints are removed and investment is long term. However, if one considers that the TMU is representative of Northeastern Ontario (and much of boreal Canada), the opportunities for Kyoto Protocol compliant afforestation for the generation of carbon offsets will likely be small for much of Canada during the first commitment period.

Key Words: Afforestation, carbon markets, carbon modelling, enabling environment, Kyoto Protocol, Northeastern Ontario, scenario development, Timmins management unit.

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1. Introduction

The Kyoto Protocol (KP) was developed to provide enforceable goals for reducing the concentration of greenhouse gases (GHGs) in Earth's atmosphere in recognition of the fact that climate change is a global concern, requiring common international policy (Metz et al. 2002, Bahn et al. 2001). Countries with abatement targets (recorded in Annex B of the KP) for the first commitment period (CP1: 2008-2012) have several options to meet their objectives: increased energy efficiency, conversion to renewable energy forms, forestry, agriculture and afforestation, as well as fiscal incentives, taxes and caps on GHG producing industries (Azar & Schneider 2002, Parker et al. 2000). More options mean lower costs, but all possibilities amount to one of two actions: decreasing sources of GHG emissions or increasing GHG sinks (Brandt & Svendsen 2002, Kurz & Apps 2001, White & Kurz 2003).

Representing a liberal environmentalist framework in which environmental health depends on the stability of an economy where market forces have precedence over command and control mechanisms, the aim of the KP is to internalize the environmental costs associated with GHG emissions into a market based decision making process (Bernstein 2002, Koziell & Swingland 2002, Landell-Mills 2002). In order to spatially harmonize marginal abatement costs (thereby minimizing total cost), mechanisms have been created to produce carbon credits (representing GHG emissions avoided or sequestered). These credits (a.k.a. offsets) allow sequestration and emission abatement to occur where it is most cost effective while counting towards the GHG balances of other regions, institutions or states (Bahn et al. 2001, Carlen 2003, Haurie et al. 2003). They also provide the incentive landowners and resource managers need to begin promoting carbon sequestration as an economically viable activity (Binkley et al. 2002). Though the exact nature of these credits has been hotly contested, all modelling exercises confirm that offset trade is the least cost option to mitigate climate change if markets can be established and transaction costs kept low (Bettelheim & d'Origny 2003, Springer 2003).

The federal government of Canada (GC) committed to decrease national emissions to 6% below 1990 levels by the end of CP1, representing ~650 Mt-CO_{2eq} (Gunter et al. 1998). How this goal is to be reached has become increasingly politicized: the provinces are uniting against the federal government, climate change science has been argued in the press and consortiums of energy industries are spending millions to influence public opinion (Chase 2002, Dentandt 2002, Karjalainen 2002, Weaver 2002, Winsor 2002, Yeldin 2002). Surprising revelations have followed: the GC lacks unity on the issue, organized labour is unanimously in favour of the protocol and Calgary is the country's most energy efficient city (Brethour 2002, Yussuff 2002, Goar 2002). This has occurred simultaneous to calls for increased funds for research, monitoring and national inventories (Lund & Iremonger 2000).

In all of the controversy, afforestation has been upheld as a potential saviour to Canada's KP woes. Various actors have claimed that its large land base and developed forest industry means that Canada can not only meet significant amounts of its KP commitments through afforestation, but that it will be a seller on the international offset market (Bernoux et al. 2002, van Kooten et al. 1999). Though several papers have discussed national and provincial opportunities for such activity (e.g. Cherry 2001, Griss 2002) none have examined the requirements necessary for the generation of KP compliant carbon offsets through afforestation for individual management units, outlining the specific steps necessary for an individual forest manager. This paper fills that gap, examining the unique characteristics of the Timmins Management Unit (TMU) in Northeastern Ontario and, using the best economic and carbon budget modelling resources available, identifying the circumstances within which an investment in afforestation for carbon offset production would be reasonable, the profit that such a project could expect and the amount of carbon that would likely be sequestered. This analysis demonstrates that unless significant action is taken to modify existing institutional frameworks, investment in the generation of KP compliant carbon offsets through afforestation in Northeastern Ontario during CP1 is not viable.

2. The Kyoto Protocol and Afforestation

The KP arose out of the recognition by the United Nations Framework Convention on Climate Change (UNFCCC) that traditional legislative means of protecting environmental services are inadequate to the task, and that mechanisms which ascribe an economic value to these services are necessary. To date, it is the only major international treaty to explicitly do so (Bettelheim & d'Origny 2002, Bonnie et al. 2002). The UNFCCC itself was created in response to the mounting evidence and near universal recognition that global warming over the last 150 years is primarily anthropogenic in origin and poses a serious threat to the stability of many environmental services. Business As Usual (BAU) modelling scenarios indicate that around 15 Gt-C were emitted to the atmosphere in the year 2000, and perhaps triple that amount will be produced by the year 2100, resulting in an atmospheric CO_2 concentration that is four times pre-industrial revolution levels. This is projected to cause a temperature increase of 1.4 to 5.8^{o}C. In order to prevent this, the protocol aims to stabilize the atmospheric concentration of CO_2 below 500 ppm (Azar & Schneider 2002). Each signatory industrialized country must reduce emissions by approximately 5% of their levels in 1990.[1] The GC has made it clear that it expects a significant proportion of Canada's commitment to come from afforestation (Anon. 2001, Griss 2002, van Kooten et al. 1999).[2]

The KP guidelines for afforested lands are found in Article 3.3 of the treaty and were finalized under the seventh conference of the parties (COP-7) at Marrakech in 2001. When considering land that historically has been forested, but has not been so since 1990, reforestation is establishing forest on land that has had tree cover recently, while afforestation occurs when the same activities establish tree cover on land that has been without trees for significantly longer. Despite this distinction both reforestation and afforestation are governed by the same rules for offset production, and they will both be referred to hereafter as 'afforestation' to distinguish them from planting as a silvicultural treatment after harvest, commonly referred to in forestry circles as reforestation (Watson et al. 2000). Regeneration after harvest does not count as the creation of a carbon sink, but neither does harvesting count as deforestation, as long as the land can be expected to regenerate to forest (Leckie et al. 2002, Watson et al. 2000, White & Kurz 2003).

Several further points about these definitions must be made. First, unlike forest management (considered under Article 3.4) there is no cap on the amount of domestic afforestation that Canada applies towards its KP commitment (Griss 2002). [3] Second,

[1] The arbitrary selection of 1990 as a target year has created a host of problems for KP implementation, including Russian hot-air and media manipulation by both proponents and opponents of the accord with respect to its scientific validity and economic efficiency. The reader is referred to Berstein 2002, Babiker & Eckaus 2002 or Reay 2002 for further discussion of this subject.

[2] It has yet to say exactly how much. Figures range from 15 – 40% (Anon. 2001, Cherry 2001, Griss 2002).

[3] There are limits on afforestation credits put towards trade with industrializing countries, but this aspect of the protocol is beyond the scope of this paper, see Jotzo & Michaelowa (2003) or Sager (2003) for more.

under the protocol forests refer to land with tree crown cover more than 10 - 30% and a minimum *in situ* potential mature tree height of 2 - 5m (whichever value is regionally appropriate). Third, biomass carbon translates instantaneously into 100% emissions upon harvesting, ignoring the residence time of carbon in fiber based products and landfills (Griss 2002). Fourth, forest carbon includes that stored in tree and understory biomass, forest litter and soils (van Kooten 1999). Finally, carbon offsets generated from afforestation are often referred to as removal units (RMUs) and are expressed in equivalent masses of carbon dioxide (t-CO_{2eq}). Just as increases in carbon sinks produce RMUs, emissions result in the cancellation of RMUs (Griss 2002). The net carbon sink less emissions is the number of RMUs produced by a project.

Necessary steps for offset generation through afforestation are found in Table 1.

Table 1 – Afforestation requirements under the KP

1. define boundaries of the area under consideration, with areas less than 1 ha not considered (White & Kurz 2003).
2. determine whether accounting is to be annual or summative over CP1,
3. develop a system for estimating emissions and removals,
4. account for carbon in above and belowground biomass, litter, dead wood and soil organic carbon,
5. account for non-CO_2 GHG emissions/removals,
6. account for the flow of carbon beginning at the start of a project,
7. report how disturbance/regeneration cycles are distinguished from deforestation,
8. develop a report for each year that includes these requirements (Griss 2002, Kurz 1999, Kurz & Apps 2001, Watson et al. 2000, White & Kurz 2003).

It is important to note that RMUs are not bankable between CPs, but can only be reissued if the biomass is still standing (Schulze et al. 2002). This has a significant impact on revenue value that will be addressed in Section 4.4.4. Furthermore, it must be remembered that there is a limit to how much carbon the biosphere can sequester (Mahli 2002, Karjalainen et al. 2002, Wicks & Curran 2003). Carbon sinks have the potential to play a significant role in meeting the protocol, but the global biosphere can sequester a maximum of 5% of the carbon projected to be released by 2100 under BAU scenarios (Mahli et al 2002). As such, carbon sinks are not substitutes for changes in energy supply, use and technology (Mahli 2002, Morishima 2002, Whittington 2002).[4] As a result, many see afforestation as an interim strategy only, but it should be remembered that afforestation produces a number of aesthetic and habitat benefits that simply reducing emissions do not (Breshears & Allen 2002, Griss 2002).

Given these definitions and requirements, a resource manager considering investing in afforestation for the generation of KP compliant carbon offsets will base her decision on the presence, form and quality of three things: credible monitoring and modelling tools, the nature of the domestic carbon market and an enabling environment. The first is necessary in order to quantify the number of carbon offsets generated by a project, the second controls the value of those offsets and the third the confidence of a project manager that the return on the investment from the outset can be estimated in advance. The following section examines each of these areas with respect to the TMU.

3. Case Study: the Timmins Management Unit (TMU)

This case study examines the different factors influencing the decision of a forest manager to pursue afforestation in the TMU for the purpose of generating KP compliant carbon offsets. The availability of credible modelling tools, the characteristics of the carbon market (considering presence, price, leakage and permanence) and the existence

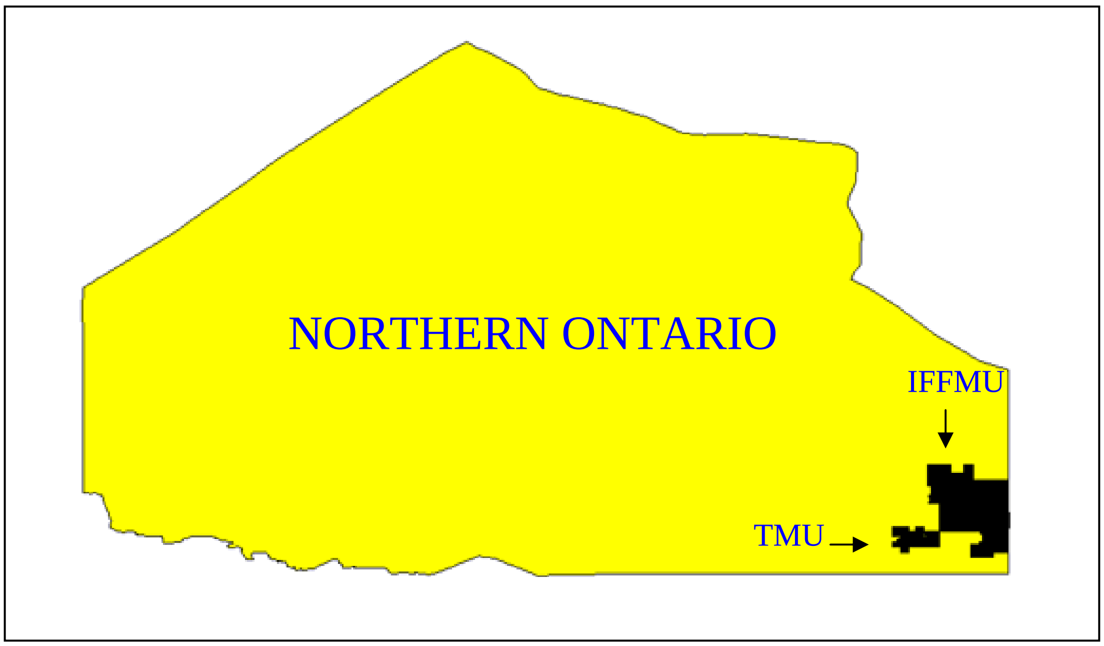
[4]It is worthwhile to note that not only is the Canadian forestry industry the single largest GHG emitter in the domestic manufacturing sector, but also that simply by retrofitting pulp and paper mills to the most efficient conventional designs, this industry could cut its emissions by over 10% at a profit. Readers are invited to refer to Bailie et al. 1999, Bruce 1999, Cox 1998 and Torrie et al. 2002 for further details.

of an enabling environment (including government support, afforestation expertise, willingness among managers and land availability) will be discussed.

3.1 Area of Interest

The TMU is 200 000 ha of land in Northeastern Ontario, and borders the Iroquois Falls Forest Management Unit (IFFMU), the forestry activities on each of which are managed by Abitibi-Consolidated (their relative locations are indicated in Figure 1).

Figure 1 – The Area of Interest



The TMU's forests are dominated by black spruce on moist lowland sites, jack pine on uplands, and trembling aspen on dry sites. Though most of the TMU is forested, significant areas of muskeg, cities (Timmins) and treeless fields also exist.

3.2 Credible Tools

Computer software which models change in carbon sinks over time rather than actually monitoring them is necessary because the nature of the quantity of interest (atmospheric GHGs) is such that current technology does not allow for accurate measurement at practical timescales. It would take thousands of measurements of the atmosphere, biosphere and pedosphere for even an instantaneous picture of landscape scale carbon pools. As a result, the best option available is to integrate the results of the many studies which attempt to define the relationships between different carbon sinks in relation to a few causal variables, such as disturbance history, climate, site class and management plans into software that model their dynamics. By developing and improving such tools, most of the problems associated with monitoring ecosystem carbon for KP compliance can be surmounted, as long as the models are used enough before CP1 that their shortcomings can be addressed (Brown et al. 2002, Kurz 1999).

For a carbon budget model (CBM) to be compliant with both the KP and the best available carbon science, it should be able to predict carbon flux for at least 11 ecological carbon sinks (aboveground tree biomass, aboveground other biomass, tree root biomass, other root biomass, coarse aboveground litter, fine aboveground litter, coarse root litter, fine root litter, quick decay soil pool, moderate decay soil pool and a slow decay soil pool (ArborVitae 1999). The ability to predict flux in both quick and slow decay wood products pools are also an asset though not required (Bird 2003). In addition, the CBM must be: able to ensure that its estimates are internally consistent, spatially explicit to the stand level, transparent such that its algorithms are verifiable, adaptable to changing definitions and accounting procedures, both cost and time efficient, able to both interpret the past and project into the future and provide estimates of uncertainty (Kurz 1999). Perhaps most importantly, these CBMs must be available and relatively easy to use so that a manager can predict the effects of proposed management plans on carbon balances accurately and with a minor investment in time and resources.

With respect to the TMU, a number of CBMs approach these requirements, though none meet them exactly. GORCAM is an example that is available, easy to execute and has been used to predict management unit scale carbon budgets in Canada. Based on the work of Schlamadinger & Marland (1996), it models nine of the required sinks, lumping the three soil sinks into a single value (making it compliant to the minimum KP standard but not reflecting the most up-to-date science) in addition to several products and landfill sinks (Bird 2003). It uses the Chapman-Richards equations to convert merchantible volume to biomass, and the user must supply empirically derived expansion factors, growth curves and average yearly temperature as a surrogate for climate. This requires a not insignificant amount of research on the part of the user. Furthermore, existing management plans in electronic format (e.g. SFMM) cannot be input directly into the model. That is, forest managers desiring to predict the effect of their activities on the carbon budget must duplicate their data input efforts for this new software, requiring a significant amount of time. Given the likelihood of high international scrutiny for forestry projects claiming KP benefits, it is by no means assured that GORCAM and similar models will meet global verification standards.

The weaknesses of GORCAM and similar models have been recognized for several years, and as a result the Canadian Forestry Service (CFS) has been developing a new CBM (the CBM-CFS3) whose release is predicted for late 2004. It will not only include all 11 ecological sinks, but provides Kyoto specific outputs, includes growth curves and biomass expansions for all tree species found in Canada for all climatic zones and site classes and allows users to import management plans from both SFMM and Woodstock directly into the model. Furthermore, it has been developed by a research team that actively participates in the development of KP reporting requirements, ensuring its KP compliance. As a result, it requires significantly less time to produce results than GORCAM, results which are more valid and more likely to meet international scrutiny.[5]

Though the soon to be released CBM-CFS3 is clearly superior to currently available models, it is not yet available and has only begun to be tested. A forest manager wishing to consider an investment in KP compliant afforestation before 2005 will have to rely on other models which, though adequate, will not necessarily pass the international scrutiny that will accompany the KP, and will require a significant investment in time and resources to produce results. As a result, though credible tools are available in the TMU which would provide the basis for a reasonably informed decision, improvements in this area are necessary before CP1 if full KP benefits are to be realized.

3.3 Economic Considerations

This section addresses the economic factors affecting KP compliant afforestation projects, including the nature of the offset market, price, leakage and permanence.[6]

3.3.1 Existence of a Carbon Market

Much like the CBM-CFS3, a Canadian domestic carbon market is currently under development, but has yet to be brought on-line. From a more theoretical standpoint,

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[5] Readers interested in technical data on or the development of the CBM-CFS3 (and its research based predecessor the CBM-CFS2) are referred to Apps et al. 2000, Bhatti et al. 2002a, Bhatti et al. 2002b, Bhatti & Apps 2000, Kurz & Apps 1999, Kurz & Apps 2001, Li et al. 2002, Li et al. 2003 and Price et al. 1997, among others.

[6] It is important to give a caveat here that economic modelling of carbon offsets is even more problematic than biological modelling of their generation, because it compounds biological uncertainty with the uncertainty of economic models (Renwick et al. 2002).

Sandor et al. (2002a) argue that a carbon credit market already exists, for there is a demand for capital to address a specific objective and that some norms for trade and participation have been developed. However, the exact form of the market mechanisms have yet to be determined, though a significant effort internationally is currently underway involving the creation of pilot markets. Pilot markets allow assumptions to be tested, verification strategies to be honed, participation to be gauged and mechanisms to be evaluated before final markets are in place, which is critical given the sums of money likely to be invested (Bohringer & Rutherford 2002, Bernard & Vielle 2003).

Analysis of pilot market mechanisms, especially the European Trading Scheme (ETS), the UK Climate Change Levy (CCL), the Chicago Climate Exchange (CCX) and the World Bank Prototype Carbon Fund (PCF) reveal the likely shape of the market (Christiansen & Wettestad 2003, Jepma 2003, Lecocq 2003, Sandor et al. 2002a, Springer 2003, Varma 2003). The extremely successful US Clean Air Act Amendment to restrict emissions of SO_x has also been widely used as a template and will continue to be influential (Bonnie et al. 2002, Sandor et al. 2002a, Sandor et al. 2002b). That is, domestic markets will have mandatory participation of all major emitters in sectoral caps and trade. Significant fines will be levied for non-compliance, the revenue from which (in addition to that from new taxes on emissions) will be recycled to decrease certain corporate taxes (such as contributions to national labour insurance). In initial stages, many emissions credits will be grandfathered on the basis of historical emissions, though research supports auction based allocation as more economically efficient. Perhaps most importantly, these new markets will not be based solely on government environmental policy, but will be worked out in dialogue with a variety of public, private and transnational partners.[7] As a result of these characteristics (especially mandatory participation with hard, enforced caps) a demand for domestic carbon offsets is virtually guaranteed and the GC will likely encourage new projects rather than endorsing old ones, in order to ensure a high price (Bernoux et al. 2002, White & Kurz 2003). However, without a currently functioning domestic market in Canada, there is certainly none in the TMU. Since the exact characteristics of this market are unknown, benefits are not guaranteed and uncertainty among decision makers will remain high.

3.3.2 Costs and Benefits

Trees have been tended and planted in Northeastern Ontario for a significant length of time, so the costs of afforestation in the TMU are well understood. When site preparation, seedling purchase, planting and tending costs are included, DeMarsh (1999) identified an average cost around 1 500 $/ha,[8] in accordance with similar values provided by van Kooten et al. (1999) and Griss (2002). Unfortunately, since carbon offsets have never been traded before, the benefits accruing to sellers are much less certain. Significant debate has occurred in economic literature as to the price of credits, but it seems that the international price will likely range from 2 to 7.5 CAD/t-CO_{2eq} (Jotzo & Michaelowa 2002, Sager 2003). Confidence in modelling tools to predict exactly how much carbon can be sequestered in the TMU thereby becomes even more important.

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[7] Readers requiring more specific information on the nature of pilot carbon markets and potential difficulties in their creation are referred to Boots (2003), Christiansen & Wettestad (2003), Fristrup (2003), Jepma (2003), Lecocq (2003), Morthorst (2003), Sandor et al. (2002a), Sandor et al. (2002b), Springer (2003) and Varma (2003).

[8] All monetary figures in this paper are reported in Canadian dollars.

3.3.3 Leakage

One of the major economic concerns of the KP is how to handle leakage, which occurs when activities that are restricted on the site of one project in order to increase carbon sequestration simply migrate offsite where they continue unabated (Babiker 2001, Kuik & Gerlagh 2003). Projects with significant leakage have no net beneficial affect on the atmospheric concentration of GHGs and can thereby not sell carbon offsets. Globally, leakage is expected to consume approximately 5 – 20 % of the total number of carbon offsets created under the KP (Paltsev 2001). As a result, a significant research effort is currently underway to develop ways to avoid leakage at the project and national scale (Binkley et al. 2002, Schwarze et al. 2002). In the case of the TMU, however, since only lands that have been without forest for a significant period of time (since before 1990) qualify for afforestation under the KP, such projects will only occur in areas not currently being managed for forest production. That is, on these lands there are no forestry activities to displace. Though afforestation could also occur on marginal agricultural land, given that the area of agricultural land has been decreasing throughout Ontario for decades, farming that was previously occurring on afforested lands is unlikely to be displaced to regions where it will result in deforestation (Duinker et al. 1999). As a result, leakage is not a concern in the TMU.

3.3.4 Permanence

Another major concern under the KP is that natural disturbance can eliminate decades worth of investment in a matter of days (Breshears & Allen 2002). This uncertainty not only decreases willingness to invest, but also overall market price

(Lecocq 2003). Unlike leakage, however, the permanence problem cannot be eliminated unless sequestered carbon is completely eliminated from the Earth-atmosphere system (an option that is neither viable nor advisable). The TMU is at significant risk of disturbance, both from fire and insect outbreak, but fortunately these risks are reasonably well known (though they are likely to change with increasing global temperature) (Harden et al. 2000, Hobbie et al. 2000, Stocks et al. 1998). A known or estimable risk can be incorporated into project design by identifying a certain proportion of the biomass that is at risk of massive disturbance (e.g. 10 %) and keeping offsets representing this fraction out of the market. These set-asides can be used to ensure that carbon offsets that are lost due to disturbance do not represent an economic loss or decrease price.[9] Given that uncertainty in the TMU is estimable, permanence is not a significant concern.

3.4 Enabling Environment

An enabling environment consists of the physical and institutional structures that facilitate projects which generate KP compliant carbon offsets through afforestation. They include: support from various levels of government, afforestation expertise, willingness among resource managers and a suitable land base for afforestation activities.

3.4.1 Government Support

Though the GC was a major proponent of securing recognition from the international community that the benefits of carbon sinks should be included in the KP, it has taken little action to date to promote them domestically (Griss 2002). At least part of this delay can be attributed to conflict with provincial governments who see

[9] This response to the permanence issue is adequate for modelling purposes but does not fully address all market ramifications impermanence implies. Responses are only currently being formulated, and readers are recommended to further papers by this author and others to be produced in the coming years.

environmental considerations (and resource management) as a uniquely provincial concern (Yeldin 2002). Apart from its conflict with the GC over jurisdiction, the government of Ontario (GO) has taken steps in recent years to make it more difficult to afforest both private and public lands through canceling all provincially operated afforestation programs (Cherry 2001). Despite repeated calls for a comprehensive government sponsored afforestation program accompanied by tax breaks and incentives to be developed in partnership with landowners and resource managers, little has been done aside from introducing the Managed Forest Tax Incentive Program (MFTIP) (Cherry 2001, DeMarsh 1999, Williams & Griss 1999). Municipal governments have also been doing their part to make afforestation increasingly difficult by refusing to direct municipal tax assessors to reassess privately held land under MFTIP guidelines, resulting in enormous tax burdens for those wishing to convert their land forest (Miller & Balsillie 2003).

This lack of government support at all levels is perhaps the biggest threat to possible afforestation projects in the TMU. Though the Model Forest Network (MFN) has been attempting to bridge this gap through its Collaborative Research Agreement with the CFS, supporting the Feasability Assessment of Afforestation for Carbon Sequestration (FAACS) and promoting afforestation as a landuse option among its partners, it cannot fill governments' role. When one considers that the other great obstacle heretofore identified is uncertainty relating to the characteristics of the carbon market (a GC responsibility) it becomes clear that various levels of government are making it more difficult to pursue afforestation for the generation of KP compliant carbon offsets in the TMU. This has resulted in the conclusion of some researchers that afforestation under the KP may be very small (Duinker et al. 1999).

3.4.2 Afforestation Expertise

With public forested land managed by a forestry company of significant size (Abitibi-Consolidated) and because of its proximity to the IFFMU, the TMU has a significant amount of experience with planting trees to maximize biomass accumulation.[10] In 1992, over 125 000 000 spruce seedlings alone were planted in Ontario (Gordon et al. 2000). When the proximity of Lake Abitibi Model Forest and the involvement of several local agencies with the MFN are also considered, one must conclude that there is high level of afforestation expertise in the TMU.

3.4.3 Willingness among managers

Though no work has been done specifically in the TMU, polls conducted throughout Ontario in 2000-2001 indicate that landowners are willing to participate in afforestation programs, with interest increasing as the size of the area owned decreases (Cherry 2001). The characteristics of such a program are important however, with partnerships between landowners, government extension agencies and forest companies and significant subsidies (90% of costs) required for program success (DeMarsh 1999). Under this sort of arrangement, where government subsidy pays 90% of costs, one would assume that revenues from carbon sequestration would also accrue to the government, but if the overall benefits were well established beforehand, it is likely that managers would be less adamant about subsidy. If the effectiveness of MFTIP could be increased or

[10] This is not precisely the same thing as afforestation for carbon sequestration, but the similarities are broad enough that one can be assured that there is a significant amount of knowledge in the TMU about how to get trees to grow well in boreal Ontario.

further tax incentives given, willingness among would likely increase further (Griss 2002). This willingness is dependent on increased government support, however, and unless this exists resource managers in the TMU will have low incentive to afforest.

3.4.4 Available Land

Though many may imagine Northern Ontario as abundant in available land, the area of suitable land for afforestation in the TMU is actually quite small if land currently under agricultural management is excluded. In this study agricultural land is excluded because, though managers of agricultural land in Ontario are willing to consider afforestation, this is only if it accompanied by significant government subsidy (DeMarsh 1999, van Kooten et al. 1999). As the shape of a provincial or national afforestation program is not the concern of this paper, but rather the decision making process of an individual project manager, lands that would require a subsidy for afforestation (that is, lands currently under some sort of active management) are not considered.

Areas in the TMU suitable for afforestation under these criteria were determined from ArcView 3.2 based landuse files as provided by Abitibi Consolidated and the Lake Abitibi Model Forest. Those which fell under the categories of ‘meadows’ or ‘brush and alder’ were considered suitable and were then distinguished according to ownership class. There are 40 ha of privately owned suitable land, and 4000 ha of publicly owned suitable land. Though in general afforestation is considered more cost effective in Northern Ontario than in Southern Ontario because of the heavily fragmented nature of the latter, in the TMU the lands under consideration are no less fragmented than one would find in the south, and in relatively small parcels (Cherry 2001). This small area of available land makes such projects in the TMU unlikely, as the modelling exercise in Section 4 will demonstrate (Fitzsimmons 2003).

None of the three elements that are necessary to make afforestation for the generation of KP compliant carbon offsets a viable investment in the TMU are satisfactory, though to varying degrees. Reasonable carbon models do exist and there is significant movement towards a model that is as good as current knowledge allows, but managers can not yet be confident that models will be KP compliant. The general shape of the carbon trade market can be deduced from the experience of pilot markets, and the strength of the TMU to fulfill these market factors can be demonstrated, but exact knowledge is required to motivate participation. Finally, an enabling environment is generally absent though this is not for any lack of suitability of the landscape. Most egregiously, to date federal, provincial and municipal governments have refused to act quickly and decisively enough to establish the conditions in the TMU necessary for afforestation projects which generate KP compliant carbon offsets to be viable investments. This is most clearly seen by the fact that only 15 000 ha/y is afforested for any reason in all of Canada, and this area is unlikely to match the area that is deforested (Duinker 1999, Fitzsimmons 2002, Fitzsimmons 2003). The following modelling exercise will demonstrate the effects of the uncertainty created by this lack of support.

4. Modelling Exercise

This section describes the costs, benefits and carbon and financial effects of hypothetical afforestation projects in the TMU through the development of a series of modelling scenarios. It will demonstrate that uncertainty regarding the timescale of investment, the market price faced by offset sellers and whether the future or current value of revenues are considered, all of which could be addressed by government action, are the primary limitations on KP compliant afforestation projects in the TMU.

4.1 The model

GORCAM-WC1 is used in this study, an Excel based stand-level version of GORCAM supplied by Woodrising Consulting Incorporated of Belfountain Ontario. Merchantable volume growth curves were those of Plonski, taken with biomass expansion factors from Alemdag (1983, 1984) and Krcmar et al. (2001) based on the methodology of Bird (2003). Though the weaknesses of GORCAM described in Section 3.2 are significant, it has been used in these types of applications before and is representative of the best tools currently available.

4.2 Scenario Development

Canada's boreal forests are an important part of the global carbon cycle, and are the largest terrestrial carbon stock in Canada (Barr et al. 2002, Bhatti et al. 2002b, Meroni et al. 2002). Though over the last century they have been a slight sink (mainly due to increasing age) in recent decades they have been a net source (Harden et al. 2000, Goodale et al. 2002, Kurz & Apps 1999, Liu et al 2002). Boreal carbon content is a result of interactions between vegetation type and succession (species selection); soil moisture, texture and nutrient availability (soil characteristics); temperature and precipitation (climate); and disturbance regime (Banfield et al. 2002, Seely et al. 2002, Trofymow et al. 2002). Given the boreal nature of the TMU, these factors (plus time and price) must be addressed in modelling scenarios.[11]

4.2.1 Timescale

Afforesation in the TMU is assumed to be immediate (beginning in 2004) on 100% of the available landbase (emulating the decision of an individual manager of a tract of land rather than a provincial program). The effect of the project is considered both over CP1 and the following 50 years (2004 – 2054). This will allow a comparison of CP1 and longterm revenues and costs.

4.2.2 Climate and Climate Change

The prevailing climate regime has a significant affect on ecosystem productivity (and therefore carbon sequestration) but the modelling thereof is difficult enough that the complex relationships between ecosystem and climate are simplified in carbon modelling to one or two parameters. In this case, average annual temperature as recorded at Cochrane by Environment Canada from the records of the last 30 years was used.

The question of climate change must now be addressed. Various effects are expected to be felt in the TMU because of climate change, and they have been predicted (among other things) to increase drought stress, wildfire intensity and wildfire duration (Barr et al. 2002, Stocks et al. 1998). It is difficult to predict the response of ecosystem productivity to these changes, however, with various researchers forecasting either increased sequestration or increased emissions depending on which soil processes they

[11] It is important to acknowledge that wetland soils and peat are the single largest terrestrial carbon sink in boreal regions, but that their dynamics are so poorly understood that they cannot even begin to be addressed by carbon budget models (Hobbie et al. 2000, Maljanen et al. 2001, Roulet 2000, Tarnocai 2000). In the case of the afforestation of barren fields, however, the accumulation of moss and peat can be assumed to be slow as long as wetland areas are not selected for afforestation.

think are most significant (Clein et al. 2002). The subject is too uncertain to make reasonable assumptions, so the best response is to select species for planting that are less susceptible to the likely future conditions of drought stress and increased fire activity.

4.2.3 Species Selection

The species selected for planting obviously have a significant affect on modelling results, and a host of species are reasonable for planting in the TMU, so species must be chosen carefully. As a result of biodiversity and invasive species concerns, only native species are acceptable (Cherry 2001, Stiers & Siebert 2002).[12] The most likely native species available for afforestation in Northern Ontario, as identified by Cherry (2001), were therefore considered.

White and red pine show promise in boreal regions, with high productivity at young ages, but some research has shown that their impact on soil organic carbon is less desirable than other species (Pregitzer & Palik 1997, Vesterdal et al. 2002). Black and white spruce have the highest productivity of species found in the TMU, especially considering their high litterfall mass and relatively rapid growth, but are susceptible to the dry conditions potentially faced in the TMU under climate change (Chen et al. 2002, Gordon et al. 2000, Yu et al. 2002). Jack pine and trembling aspen are the best suited for afforestation in the TMU given the conditions likely to be created by climate change since they both grow well under dry conditions and can have high short term sequestration (especially aspen). A mix of 50% jack pine and 50% trembling aspen were therefore chosen for afforestation in these modelling scenarios, which is in line with the

[12] Though the afforestation of hybrid poplar has become popular because of its quick growth, it requires careful tending, moist conditions, is prone to insect outbreak and disease and has not responded well in experimental plantings in Northern Ontario (Cherry 2001, Perry et al. 2001, Samson et al. 1999).

recommendations of Cherry (2001) and Duinker (1999). There is no difficulty in getting these species from local seed zones (Cherry 2001).

4.2.4 Harvest and Disturbance

Though under the KP aboveground tree biomass is considered to be 100% emitted to the atmosphere upon harvesting, harvest does not necessarily result in a net emission when the entire landscape and belowground carbon sinks are considered. It is therefore possible to balance the economic returns from harvest against those of carbon sequestration to maximize revenue generation, and to use carbon models to contribute to the determination of optimal rotation ages and silvicultural treatments (Lee et al. 2002, Peng et al. 2002). The long term effects can also be identified, for though many carbon pools recover quickly from disturbance, some result in sources not only the year they occur, but for years to come through higher soil temperatures and accelerated decay rates (Chen et al. 2002). Despite the obvious value of studying the effect of disturbance on carbon stocks, however, these scenarios do not include it. The purpose of this exercise is to determine whether afforestation for the generation of carbon credits in and of itself is a reasonable investment in the TMU at this time, not to examine all the potential revenue streams that could accrue to such a project. It should nonetheless be remembered, though, that there are other benefits to afforestation projects than simply KP compliant offsets.

4.2.5 Soil Characteristics

Soil characteristics are critical for landscape scale carbon modelling because soils contain approximately three times as much carbon as terrestrial vegetation (globally) and have the longest residence time of terrestrial pools, especially in boreal forests (Bhatti et al. 2002b). In particular, the history of the area to be afforested is important, because soil respiration and decay will continue decades after aboveground biomass has been removed, and will have important effects on the timing and value of the equilibrium soil carbon will reach after an area has been afforested (Bashkin & Binkley 1998). The amount of soil carbon lost when forest is converted to agriculture is between 20 and 40% in Ontario, regardless of initial carbon content or soil texture, with the vast majority lost within the first 20 years (Carter et al. 1998, Ellert & Gregorich 1996, Paustian et al. 1997, West & Post 2002). In this study, since the only fields under consideration have been cleared for over 25 years and are not currently managed for agriculture, the main effects of deforestation have already occurred, so a current soil carbon value is sufficient.[13]

Another soil value important to this study is productivity, including available soil nutrients, relief, some climatic factors and drainage, and all of which are summarized by site class (Marland & Schlamadinger 1997). Based on the recommendation of Duinker (1999) a high site class value for these lands was assumed (Site Class 1), but a lower class was also modelled, for comparison (Site Class 2). Duinker (1999) recommends a high site class because forests cleared for agriculture or pasture typically represent the most productive lands in an area, which is why they were chosen for clearance in the first place. Drainage is therefore assumed not to be a constraint, because in addition to the previous argument, lands where drainage is a serious problem would be classified as 'muskeg' in the classification map mentioned in Section 3.4.4.[14] Furthermore, yearly

[13] This value can be determined by inputting climate and regional data into a treeless scenario and running the model until a steady soil carbon state is reached.

[14] Drainage has several important impacts on the carbon cycle in boreal Ontario, including increasing the soil sink (through decreasing decomposition rates) and modifying the impact of soil texture on aboveground biomass: soils with poor drainage and high clay content decrease growth (because of water logging), soils with good drainage and high clay content increase growth (as a result of more soil nutrients)

totals should be considered rather than continuous tracking of carbon levels, because there are important seasonal differences between whether a landscape is a site or sink (Pypker & Fredeen 2002).[15]

Regardless of soil characteristics, however, and without minimizing their obvious importance on carbon stocks over the landscape, it is important to remember that soil pools are very stable of the long term, and increase very slowly even when biomass increases quickly (as is the case with the afforestation of grasslands and fields) (Seely et al. 2002). Studies indicate that in scenarios like those being analyzed here soil carbon will increase significantly (mainly from inputs of forest litter) but only 100 – 200 years after afforestation (Bouwman & Leemans 1995, Menyailo et al. 2002, Pregitzer & Palik 1997, Vesterdal et al. 2002). As a result, the contribution of soil is not likely to be significant in the TMU over the timescale considered here.

4.2.6 Opportunity and Transaction Cost

In this case, the only costs considered are the costs of afforestation itself (addressed in Section 3.3.2). Though some researchers have noted that opportunity and transaction costs must be considered, and that they are extremely problematic, these were not included in this analysis (van Kooten et al. 1999). Opportunity cost is not significant in this case because the lands under consideration in the TMU have not been under active management for some time, for all intents and purposes they have been abandoned. Therefore, there are no alternative uses in competition with afforestation whose potential

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(Banfield et al. 2002, Bhatti & Apps 2000, Bhatti et al. 2002a, Bhatti et al. 2002b, Harden et al. 2000, Vesterdal et al. 2002).

[15] That is, since biomass is the major driver of carbon accumulation in the short term, boreal forests are net sinks in the growing season, but often sources in winter months when growth has basically stopped but belowground respiration continues.

revenue could be called an opportunity cost.[16] Transaction cost has not been considered because little is known about the nature of these costs in a KP compliant project, though recent work suggests that they could be low relative to expected returns, and at the very least significantly lower than other costs (Sager 2003). Since the actual costs of afforestation itself will be so dominant, it is not necessary to include transaction costs as they will not have a major effect on the outcome. If it is determined by future research that they are important, they could easily be incorporated into similar studies to this one.

4.2.7 Modelling Scenarios

Tables 2 and 3 summarize the characteristics of the modelling scenarios. Only the afforestation costs and species mix remain constant across all scenarios. In addition, the effect of a fungibililty constraint requiring the banking of 10% of all offsets against disturbance was applied to S11 to study its effect.

4.3 Results

Table 4 displays the results of the modelling scenarios of section 4.2.7.

[16] If a provincial afforestation program were being designed, however, opportunity costs would likely be the single most important factor influencing the participation of resource managers (DeMarsh 1999).

Table 2 – Modelling Scenarios (Private land)

Variable	S1	S2	S3	S4	S5	S6	S7	S8
Area (ha)	40[17]	40	40	40	40	40	40	40
Ownership	Private	Private	Private	Private	Private	Private	Private	Private
Species Planted	50/50 JP/TA	50/50 JP/TA	50/50 JP/TA	50/50 JP/TA	50/50 JP/TA	50/50 JP/TA	50/50 JP/TA	50/50 JP/TA
Productivity	SC1	SC1	SC1	SC1	SC2	SC2	SC2	SC2
Project Length	2004-2012	2004-2012	2004-2054	2004-2054	2004-2012	2004-2012	2004-2054	2004-2054
Costs ($/ha)	1500	1500	1500	1500	1500	1500	1500	1500
Price ($/t-$CO_{2eq}$)	2	7.5	2	7.5	2	7.5	2	7.5

Table 3 – Modelling Scenarios (Public Land)

Variable	S9	S10	S11	S12	S13	S14	S15	S16
Area (ha)	4000	4000	4000	4000	4000	4000	4000	4000
Ownership	Public	Public	Public	Public	Public	Public	Public	Public
Species Planted	50/50 JP/TA	50/50 JP/TA	50/50 JP/TA	50/50 JP/TA	50/50 JP/TA	50/50 JP/TA	50/50 JP/TA	50/50 JP/TA
Productivity	SC1	SC1	SC1	SC1	SC2	SC2	SC2	SC2
Project Length	2004-2012	2004-2012	2004-2054	2004-2054	2004-2012	2004-2012	2004-2054	2004-2054
Costs ($/ha)	1500	1500	1500	1500	1500	1500	1500	1500
Price ($/t-$CO_{2eq}$)	2	7.5	2	7.5	2	7.5	2	7.5

4.4 Discussion

Though several pertinent observations can be drawn from these results, this section will address the four most important: the impact of site class assumptions, price, project length and whether current or future price is considered.

4.4.1 The impact of site class

Most obviously, the higher the productivity of the site, the more carbon is sequestered. A comparison of S16 and S12 or S8 and S4 reveals that the difference

[17] All suitable land in the TMU is assumed to be managed by two decision makers (one private, one public) because of the small areas involved, though this is clearly not the case. This is done for the sake of the analysis, since these results can be extrapolated over much on Northeastern Ontario.

between SC1 and SC2 is approximately 50% of the value of the latter, clearly a very significant impact, and similar to that found by Duinker (1999). This effect can clearly be seen in Figure 2. Note that ecosystem carbon accumulates faster in both trembling aspen and jack pine plantations at SC1 than SC2, which is not surprising. What is more interesting is that in the long term, SC2 trembling aspen sites accumulate more carbon than SC1 jack pine, indicating that regardless of project length and site class, managers should consider trembling aspen superior (from a purely carbon oriented perspective) than jack pine. Given Duinker's (1999) recommendation to assume a high site class, and Betts' (2000) observation that conifer plantations generally have higher sequestration potential than natural forests at mid to high latitudes, assuming high productivity seems reasonable, but managers should carefully consider whether this assumption is reasonable in their particular case, given the effect poor site class could have on their project.

Table 4 – Results of the Modelling Exercise

Scenario	Carbon Sequestered (t-CO_{2eq})	Profit/Loss ($)
S1	40	-59 700
S2	40	-58 800
S3	6 060	-11 500
S4	6 060	122 000
S5	13	-59 900
S6	13	-59 600
S7	4 740	-22 000
S8	4 740	82 254
S9	4 030	-5 970 000
S10	4 030	-5 880 000
S11	606 000	-1 150 000
S12	606 000	12 200 000
S13	1 310	-5 990 000
S14	1 310	-5 960 000
S15	474000	-2 210 000
S16	474000	8 230 000

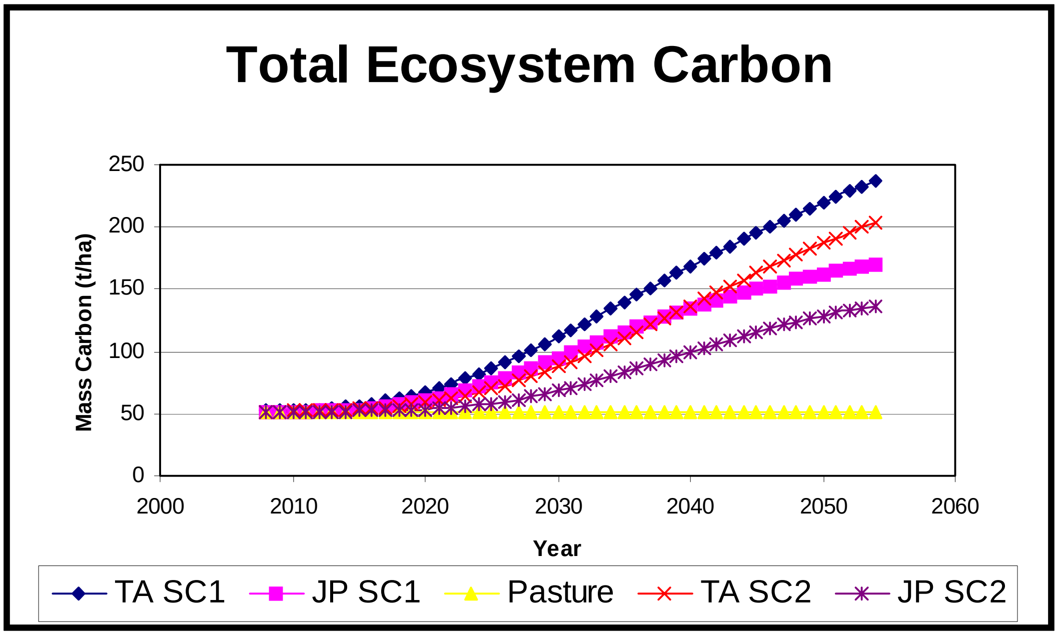

Figure 2 – Total ecosystem carbon under various Site Classes

4.4.2 The impact of project length on carbon sequestration

One of the most significant impacts on sequestration is the timescale of the project. A comparison of S1/S2 to S3/S4 or S9/S10 to S11/S12 clearly shows the major impact time has on carbon accumulation at a landscape scale. A 10-fold increase in project length results in over a 100-fold increase in carbon sequestered in the latter case. Figure 2 also demonstrates this effect clearly. Since the fact that the accumulation of aboveground biomass is the major driver of increases in ecosystem carbon in the first century of an afforestation project has already been established, it is clear from these results that the slow growth of native trees in the TMU over the short term means that afforestation projects will not generate any significant benefits during CP1.

4.4.3 The impact of price

Examining the role of offset price in the modelling exercise reveals several important aspects of afforestation projects in the TMU. First, for all scenarios describing projects that only run for CP1, both the highest and lowest likely price yield money losing projects. In fact, the break even offset price for a CP1 project is 1150 \$/t-CO_{2eq}, a ludicrously high price that could not possibly be reached even though prices are expected to rise in future commitment periods (Griss 2002). Clearly, price is insignificant for CP1 and no afforestation based offset generating project in the TMU will yield a profit in the short term. Second, in the long term price is very significant. Consider the difference between S11 and S12 or S15 and S16. Depending on the price in future CPs, afforestation projects in the TMU could be quite profitable. In the SC1 scenarios, the break even price for long term investment is only 2.50 \$/t-CO_{2eq} and for SC2 only 3.20 \$/t-CO_{2eq}, both very close to the minimum expected price. Therefore, though in the short term price is insignificant, in the long term it is a critical control on project viability.

4.4.4 The impact of current or future value

An important assumption that has not been examined to this point is the timing of benefits. Afforestation costs are assumed to occur up-front, in the first year of activities, which is reasonable. However, revenues are also assumed to occur in the first year of the project, which may or may not reflect reality. Under the KP, offsets generated from sequestration cannot be banked between CPs, but only reissued if the biomass is still standing (Shulze et al. 2002). Therefore, only offsets already generated can be sold on the market. While this may leave room for a project manager signing a long term contract with a buyer to supply them with a certain number of offsets over the next 50 years, it will certainly limit the buyer's use of those offsets to those already extant, which may make them unwilling to purchase credits up-front. If the present value of credits (at a 5 % interest rate) sold in future CPs is considered (assuming nine five-year CPs starting in 2008 and ending in 2052), S11 would lose \$ 4.9 million rather than \$ 1.2 million and S12 would lose \$ 2.0 million rather than make \$ 12.2 million. The break even price becomes \$ 11.30/t-CO_{2eq}. It should be noted that though this price is higher than the maximum price considered likely for CP1, it is projected that in future CPs offset price will rise to at least this much (Williams & Griss 1999). Therefore, price will have to rise considerably higher than those predicted for CP1 if managers in the TMU are to be willing to invest in afforestation for carbon offset generating projects.

The overriding theme through this analysis is one of uncertainty. Current carbon models may be adequate for KP modelling and better models should be coming soon. The nature of the market can be approximated, and the future value of offsets produced can be predicted to a certain extent. That is, the future for such projects may be bright, but it may not be. The major cause of this uncertainty is tangible government support – an enabling environment – that has hitherto been absent in Canada. It is up to the various levels of Canadian government to define the nature of the carbon offset market, to give price guarantees, to set banking rules, in short, to provide certainty to Canadians about how the KP will be implemented in Canada. Until this happens, this analysis demonstrates that resource managers in the TMU (and, in fact, all of Canada) will have no incentive to participate in offset generating afforestation projects not only during CP1, but for future CPs as well. This result is not surprising considering the low growth rates found through much of Canada, and has led other researchers to the same conclusion

(Price et al. 1997). However, the other feature of this analysis of unique significance is its demonstration that under quite reasonable conditions (a high price in future CPs and a few thousand hectares of available land of a high site class afforested using native species) such projects are viable investments in the TMU (and therefore, perhaps, much of boreal Canada) even when the only revenue generated is from carbon offset sales. However, since it takes such a long time in these areas to accumulate significant amounts of carbon, activity must commence immediately for this to be the case.

5. Recommendations and Conclusions

The following conclusions can be drawn from this paper.

1. Existing carbon models currently available in the TMU cannot be guaranteed to be acceptable under KP guidelines, neither is their ease of use nor data requirements acceptable to resource managers, though in the near future such models will be available.
2. Certain characteristics of Canada's carbon offset market can be predicted at this time but cannot be fully known.
3. Despite support from the MFN, an enabling environment is absent in Canada, including the TMU, and the uncertainty created by this lack of government commitment will keep managers from engaging in afforestation for the purpose of generating KP compliant carbon offsets in time for CP1.
4. Under certain conditions (offset price greater than \$11.30/t-CO_{2eq}, a 50 year planning horizon, a mix of trembling aspen and jack pine, available high site class

land and interest rates less than or equal to 5%/a) afforestation projects generating KP compliant carbon offsets are a viable investment in the TMU.

From these conclusions, the following recommendations can be justified.

1. Current efforts to ready the CBM-CFS3 for release should be encouraged by both the MFN and CFS (and other government bodies).
2. Efforts to reform property taxation, create provincial afforestation programs and describe the national carbon market should be supported by all levels of government in order to create an enabling environment for carbon offset generating afforestation projects.
3. Research into alternative revenue streams from afforestation projects should continue, increasing the viability of such projects even more.
4. Agriculturalists, municipalities, native groups, crown land tenure holders and other land managers should put pressure on various levels of government to accelerate their efforts to create an enabling environment for afforestation projects, the first step of which is the elaboration of a KP compliant domestic carbon offset market.

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